Recolonization by fishes of a rocky intertidal pool following repeated defaunation

R. Lardner, Walter Ivantsoff and Lucy E. L. M. Crowley

School of Biological Sciences, Macquarie University, NSW. 2109

ABSTRACT

An intertidal rock pool at Seal Rocks, New South Wales, was repeatedly defaunated during summer or autumn between 1969 and 1987 using the ichthyocide rotenone. The fish assemblage was of moderate diversity, dominated by juveniles of subtidal species. Changes in the composition and numbers of species of this assemblage were assessed on both a long-term and short-term basis. The long-term study covered a period of 19 years; the short-term study was from March to May 1986. While considerable variation was observed in the numbers of the component species over the long-term collections, species composition remained relatively constant. In short-term studies recolonization of the area was initially rapid. Initial recolonization was dominated by intertidal species, such as *Torquigener pleurogramma*, while subtidal species were more numerous in the long-term. This study is a preliminary observation of the fauna composition in one selected tide pool subjected to repeated defaunation.

INTRODUCTION

The biology of intertidal fish assemblages of the world has received little attention (Gibson 1982) despite their importance (Bennett *et al.* 1983) in that zone. While there are many studies on larval fish assemblages in Australia, they are based on marine and estuarine fishes (see Miskiewicz 1991). These studies do not refer to tide pools as nursery areas. Previous work on intertidal fish often concentrated on the biology of a single taxon (e.g. Gibson 1967; Marsh *et al.* 1978; Richkus 1978; Butler 1982) with relatively few studies concentrating on the ecology of intertidal assemblages. As a consequence, the principal factors which regulate fish assemblages remain unclear.

It is known that assemblages of intertidal fish are partly regulated by local environmental parameters. Short-term seasonal variations in temperature influenced populations of tide pool fishes in the Gulf of California (Thomson and Lehner 1976), central Californian coast (Yoshiyama 1981) and in an intertidal mussel bed in England (Jones and Clare 1977). Grossman (1982) found that suitable food availability was the main environmental factor affecting assemblage structure of intertidal fish on the central Californian coast. The physical characteristics of tidal pools, such as pool size and amount of rock cover available, were considered possible regulators of assemblages of intertidal fish by Gibson (1972) and Bennett and Griffiths (1984).

Behaviour patterns of species may also influence intertidal fish assemblages. Studies on movements of some intertidal species (e.g., Gibson 1967; Richkus 1978) have shown that several tide pools may be found within an individual's home range and, therefore, its capture from a particular pool is probably by chance. Subtidal schools of the subtidal damselfish *Abudefduf saxatilis* were observed to move into the littoral zone and disperse during winter (Fishelton 1970). In addition, many subtidal species actively seek an intertidal habitat during some stage of their life cycle. Sale (1969) and Beckley (1985a) had shown that subtidal pools are important nursery areas for many subtidal species while Potts (1980) suggested that these juveniles may receive protection from subtidal predators. It was also suggested by Lenanton (1982) that several commercially important southwestern Australian fish species might use the inshore marine environment as alternative non-estuarine nursery areas.

Unlike many intertidal organisms, fish have considerable mobility, making sampling of populations or assemblages difficult. Therefore, the collection of fish found within the intertidal zone is usually performed at low tide when the fish are concentrated in tidal pools (Bennett *et al.* 1983). Most recent studies have used the ichthyocide rotenone to sample such fish assemblages. This method usually results in complete defaunation of the area sampled, providing a vacant habitat for recolonization.

Early studies of tide pool recolonization by Bussing (1972) and Marsh *et al.* (1978) suggested that recolonization, mainly by juveniles, was slow. On the other hand, Beckley (1985b) concluded that recolonization of tidal pools at Blue Hole, South Africa, was rapid and included both juvenile and adult fish. All known studies of tide pool recolonization deal with repopulation after intervals of three weeks or more.

Rates of recolonization are probably related to factors such as local abundance, season and a species' home range. Gundermann and Popper (1975) as well as Beckley (1985b) considered the proximity of adjacent unaffected populations to be an important factor in the recolonization of experimentally defaunated areas. Beckley (1985b) also showed that season affected the population densities of recolonizers. The extent of the home range for a particular species was shown by Marsh *et al.* (1978) to influence its recolonization of adjacent areas.

The long-term study was carried out to determine the constancy of faunal composition of an intertidal pool, defaunated over a period of years. The short-term study determines initial colonizers of the same intertidal pool repeatedly defaunated over a very short time period (from hours to days).

MATERIALS AND METHODS

Study Area

The study was conducted in a single rock pool at Sugarloaf Point, Seal Rocks, New South Wales. (32°27′ S, 152°31′ E, Fig. 1). At low tide, the surface area of the pool is approximately 100 m^2 while the depth of the pool is up to 1.3 m. The northern edge of the pool is a boulder field which is completely uncovered at low tide. Rock walls, at least one metre high comprise the eastern, western and southern margins of the pool. In places the rock walls overhang the water forming shallow caves and crevices. The southern margin is dissected by several narrow (from about 5 to 25 cm), shallow passages, some of which remain in

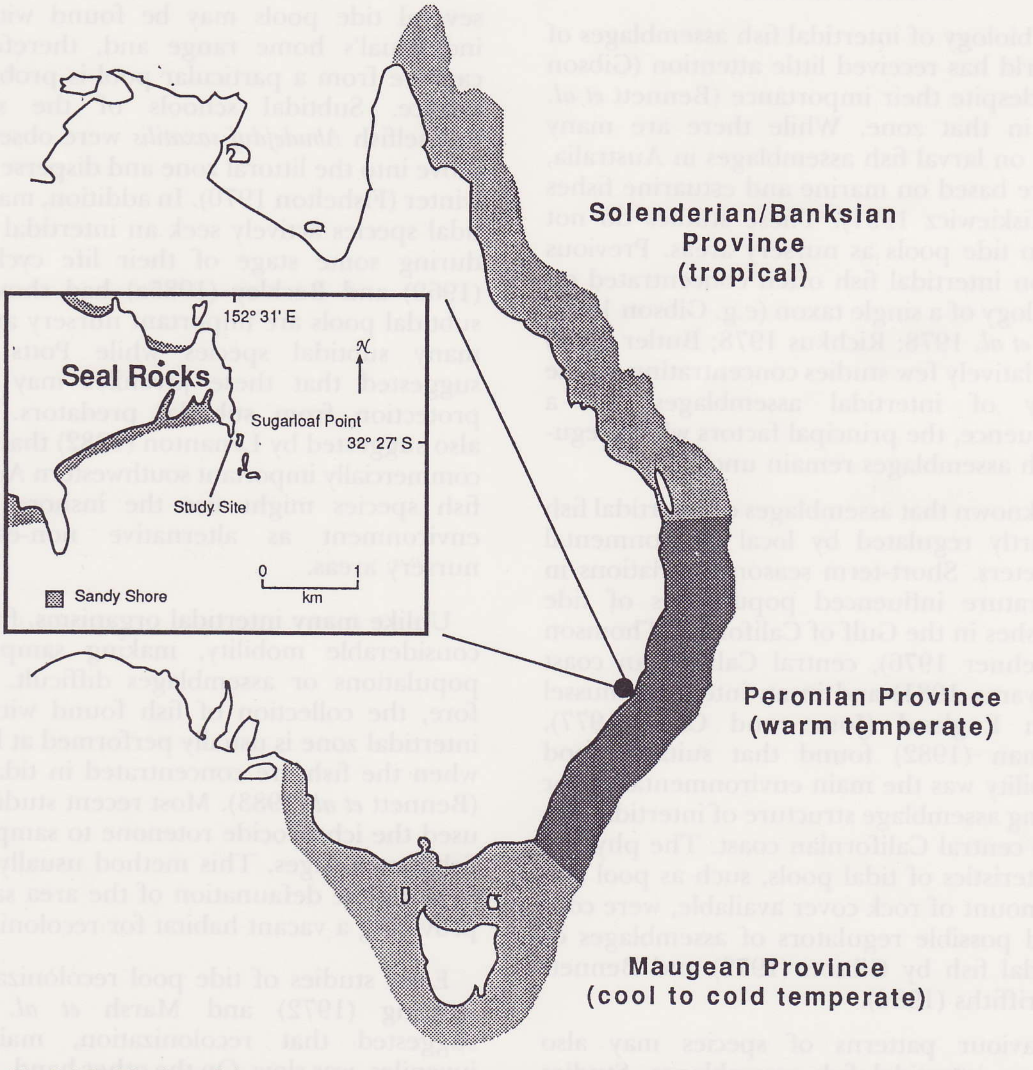

Fig. 1. Modification of the marine provinces described by Briggs (1974) into: Tropical; Warm temperate; and Cool temperate regions. Inset: location of the tidal pool investigated in the Seal Rocks area.

contact with subtidal areas at low tide. The mean tidal range during summer and autumn was 1.1 m. The water temperature during the study period ranged from 19 to 26° C.

The tide pool occurs in the Wootton Bed Formation, traversing beds of arenite, mudstone and conglomerate (Engel 1962). Rocky cover within the pool is provided by boulders, cobbles and pebbles. There are also several patches of coarse sand. Major algal types identified, using the figures of Fuhrer *et al.* (1981), included the rhodophytes *Amphiroa, Gelidium* and *Nizymenia*; the phaeophytes *Ecklonia, Sargassum* and *Zonaria*; and the chlorophyte *Codium.*

Collection

The pool was sampled on numerous occasions during summer and autumn between 1969 and 1978 as part of undergraduate biology courses at Macquarie University. All collections were conducted at low tide with any connections between the pool and adjacent subtidal areas being netted off. Powdered rotenone (3 kg mixed to a paste with bio-degradable detergent and water) was distributed throughout the pool and poisoned fish were collected with hand nets. A thorough search of the pool, including beneath rocks, was conducted by snorkelling, ensuring a complete collection. Collected fish were fixed in 10 per cent formalin and identified. For each collection the fish were counted and standard length (SL) measured to the nearest mm. Selected fish were preserved in 70 per cent ethanol and included in the Macquarie University specimen collection.

The history of collections and the amount of data available for each collection are presented in Table 1. Complete records were not available for some collections. The long-term observations were based mainly on the collections from 1973, 1978(i); 1981, 1982, 1984(ii), 1985, 1986(i) and 1987, but the numbers of species in the 1969, 1971 and 1972 collections were also used. The observations of short-term recolonization were based on the 1986(ii-v) collections.

From the collections the following data were obtained:

(1) total number of species
(2) total number of individuals of each species (S_i)
(3) total number of individuals (N)

Table 1. The history of rotenone collections from the Seal Rocks tidal pool.

Data	DFC	DPC	WT(°C)	Data available
*29 Mar., 1969	0	—	—	SP
18 August, 1970	508	508	—	SP
*9 May, 1971	772	264	20	SP, SA
*24 May, 1972	1 153	381	—	SP, SA
11 May, 1973	1 146	293	22	SP, TA, SLR
1974	—	—	—	SP
21 May, 1976	2 552	—	—	None
*18 Jan., 1978(i)	3 160	608	19	SP, TA, SLR
21 Jan., 1978(ii)	3 163	3	20	SP, TA
*15 Mar., 1981	4 312	1 149	26	SP, TA, SLR
*17 Feb., 1982	4 651	339	—	SP, TA, SLR
10 Feb., 1984(i)	5 374	723	—	None
*1 May, 1984(ii)	5 456	82	—	SP, TA, SLR
*2 Feb., 1985	5 732	276	—	SP, TA, SLR
*15 Mar. 1986(i)	6 138	406	21	SP, TA, SLR
**15 Mar., 1986(ii)	6 138	0.5	23	SP, TA, SLR
**27 Mar., 1986(ii)	6 150	12	20	SP, TA, SLR
**4 May, 1986(iv)	6 188	38	21	SP, TA, SLR
**7 May, 1986(v)	6 191	3	21	SP, TA, SLR
*3 May, 1987	6 552	361	—	SP, TA, SLR

*Collections used in long-term data.

**Collections used in short-term data.

DFC, days since first collection; DPC, days since previous collection; WT, water temperature.

Data available: SP, record of species collected only; SA, some numerical data; TA, total numbers of individual fish; SLR, standard length ranges.

Using information gathered from observation and the available literature, component species were categorized according to their zoogeographical and behavioural affinities. The categorization into zoogeographical groups was based on the eastern-Australian marine provinces described by Briggs (1974) (Fig. 1; Table 2). Three categories were recognized:

(a) Tr, tropical — species which have a principal distribution including the Solanderian/Banksian province;
(b) W, warm temperate — species which are distributed throughout the Peronian province but which have a potential distribution which includes both the Solanderian/Banksian provinces;
(c) C, cool temperate — species which have a principal distribution including the Maugean province.

Species' behaviour was classified as (Table 2):

(i) Ag, aggregating — species which swim in schools or congregate in groups;
(ii) So, solitary — species which do not congregate, tending to be alone or in pairs;
(iii) Cr, cryptic — species which are camouflaged or exhibit secretive behaviour (Thomson and Lehner 1976)
(iv) Ter, territorial — species which defend a particular area.

For each collection, the percentages of individuals (N%) and species (S%) belonging to these categories were determined.

Table 2. Categorization of the numerically dominant species inhabiting a tidal pool at Seal Rocks.

Species	Common name	Family	ZA	BA
Torquigener pleurogramma	Weeping toadfish	Tetradontidae	W	Ag
Tetractenos glaber	Smooth toadfish	Tetradontidae	W,C	Ag
Abudefduf vaigiensis	5-banded damselfish	Pomacentridae	W	Ag
Myxus elongatus	Sand mullet	Mugilidae	W	Ag
Centropogon australis	Fortescue	Scorpaenidae	W	So, Cr
Chironemus marmoratus	Kelpfish	Chironemidae	W	Ag, Cr
Lepidoblennius haplodactylus	Jumping joey	Tripterygiidae	W	So, Cr, Ter
Microcanthus strigatus	Stripey	Scorpididae	W	So, Cr
Petraites nasutus	Long-nosed weedfish	Clinidae	W	So, Cr, Ter
Acanthistius ocellatus	Wirrah cod	Serranidae	W	Ag
Epinephelus daemelii	Saddled rock cod	Serranidae	W	Ag
Heteroclinus whiteleggii	Whitelegg's weedfish	Clinidae	W	Ag, Cr
Parablennius intermedius	False Tasmanian blenny	Blennidae	W	Ag
Scorpis lineolatus	Silver sweep	Scorpididae	W	Ag
Acanthurus triostegus	5-banded surgeonfish	Acanthuridae	Tr	So, Cr, Ter
Girella elevata	Rock blackfish	Girellidae	W	So, Cr, Ter
Atypichthys strigatus	Mado	Scorpididae	W	So, Cr, Ter
Velambassis jacksoniensis	Port Jackson perchlet	Ambassidae	W	So, Cr, Ter
Bathygobius krefftii	Kerfft's goby	Gobiidae	W	So, Cr
Parma microlepis	White-ear scalyfin	Pomacentridae	W	So, Cr
Vauclusella annulata	Threefin blenny	Tripterygiidae	W	So, Cr, Ter
Bathygobius fuscus	Brown goby	Gobiidae	Tr	So, Cr, Ter
Pardachirus hedleyi	Southern peacock sole	Solidae	W	So, Cr
Synaptura nigra	Black sole	Solidae	W	So, Cr
Istiblennius edentulus	Rippled blenny	Blennidae	Tr	So, Cr, Ter
Gymnothorax prasinus	Green eel	Muraenidae	W	So, Cr, Ter
Notolabrus gymnogenis	White-spotted parrotfish	Labridae	W	So
Crinodus lophodon	Rock cale	Aplodactylidae	W	Ag, Cr

Categories: ZA, Zoogeographic affinity: W, warm temperate; Tr, Tropical; C, cool temperate; Ba, Behavioural affinities: Ag, aggregating; So, solitary; Cr; Cryptic; Ter, territorial.

Life-history stages of the most abundant species (major species) were determined by comparison of SL ranges collected with the recorded limits for larvae (Leis and Rennis 1983) and adults (Munro 1954-58; Munro 1967; Scott *et al.* 1974; Grant 1982)

RESULTS

From all collections, 99 species belonging to 42 families were identified from the Seal Rocks tide pool. The major species and the zoogeographical and behavioural categories for these species are presented in Table 2. Species less important in terms of numbers or presence (minor species) are listed in Table 6.

Long Term Collections

Over the years, 94 species belonging to 39 families were collected from the pool. Of these, the numbers, length range and life-history stage of the 25 top-ranked species are given in Table 3. These represent 98 per cent of the fish collected in the long-term collections. The average number for each collection was 476 individuals in 22 species. *Torquigener pleurogramma* (24.1%) and *Tetractenos glaber* (11.4%) were the most numerous species in the assemblage. The dominant families, in terms of individuals, were Tetradontidae, Clinidae, Pomacentridae, Mugilidae, Scorpididae, Chironemidae and Scorpaenidae (Table 2).

All species listed in Table 3 occurred as juveniles, suggesting the importance of this pool as a nursery habitat. Larval stages of *Myxus elongatus*, *Microcanthus strigatus* and *Centropogon australis* were also collected. Adults of only a few species were collected (Table 3). These were *Velambassis jacksoniensis, Tetractenos glaber, Chironemus marmoratus, Acanthistius ocellatus, Centropogon australis, Gymnothorax prasinus, Crinodus lophodon, Lepidoblennius haplodactylus, Petraites nasutus, Parablennius intermedius* and *Istiblennius edentulus.*

The percentage of species and individuals belonging to the zoogeographical and behavioural groups are presented in Table 4. These data are based on the species listed in Table 3. Among the zoogeographical categories, warm temperate species dominated. They accounted for 98.1 per cent of the individuals and 92 per cent of the species. As the pool at Seal rocks is in the Peronian Province (warm temperate) this result was to be expected. Cool temperate species comprised less than 0.5 per cent of all fishes. A small percentage of individuals and species were regarded as tropical (8%) of species. The tropical and the cool temperate species are outside the normal limits of their range.

The aggregating species dominated in numbers of individuals, but not in species present (Table 4). Conversely, solitary species,

Table 3. Total number of individuals of each species, standard length, length range and life-history stage data for the 25 numerically most dominant species collected from the Seal Rocks tidal pool during the *long-term series of collections (1969–87).*

Species	(N%S_l)	Length range (mm) and life-history stage	
1. *Torquigener pleurogramma*	24.1	25–57	J
2. *Tetractenos glaber*	11.4	21–98	J–A
3. *Abudefduf vaigiensis*	8.8	12–82	J
4. *Myxus elongatus*	8.5	4–56	L–J
5. *Lepidoblennius haplodactylus*	7.0	17–91	J–A
6. *Microcanthus strigatus*	6.1	9–79	L–J
7. *Chironemus marmoratus*	5.5	45–205	J–A
8. *Centropogon australis*	5.4	9–93	L–J–A
9. *Petraites nasutus*	3.2	14–52	J–A
10. *Scorpis lineolatus*	2.2	32–101	J
11. *Parablennius intermedius*	2.1	13–80	J–A
12. *Acanthistius ocellatus*	1.7	13–180	J–A
13. *Acanthurus triostegus*	1.6	22–56	J
14. *Epinephelus daemelii*	1.3	21–147	J
15. *Heteroclinus whiteleggi*	1.3	30–52	J
16. *Atypichthys strigatus*	1.3	16–77	J
17. *Velambassis jacksoniensis*	1.2	35–55	J–A
18. *Girella elevata*	0.9	40–112	J
19. *Bathygobius krefftii*	0.9	17–37	J
20. *Parma microlepis*	0.9	14–58	J
21. *Vauclusella annulata*	0.8	22–36	J
22. *Synaptura nigra*	0.4	8–25	J
23. *Istiblennius edentulus*	0.2	30–75	J–A
24. *Gymnothorax parsinus*	0.2	102–710	J–A
25. *Crinodus lophodon*	0.2	59–241	J–A

Life-history stages: L, larval; J, juvenile; A, adult.

Table 4. Percentages of species (S%) and total individuals (N%) belonging to the zoogeographic and behavioural groups for the 25 species listed in Table 3.

Category	Percentage species (S%)	Percentage total individuals (N%)
ZOOGEOGRAPHIC AFFINITY		
Warm temperate	92	98.1
Tropical	8	1.9
Cool temperate	0	0.0
BEHAVIOURAL AFFINITIES		
Aggregating	32	67.2
Solitary	64	32.7
Cryptic	68	39.2
Territorial	32	13.8

which are commonly both cryptic and territorial had fewer individuals but greater species diversity.

The number of individuals belonging to each major species appeared to vary, with only three species (*C. marmoratus, M. strigatus* and *E. daemelii*) occurring in every collection. The numbers of species varied little among the long-term collections. Considerable variation was observed, however, in the numbers of individuals collected from the Seal Rocks tide pool over the long-term collections (Tables 3, 5).

Short-term Collections

A total of 34 species belonging to 20 families was collected from the pool during 1986(ii-v). Five species had not been collected from the pool previously. The 16 top-ranked species are listed in Table 5. These account for over 98 per cent of individuals. Other species are listed with minor species from both short and long-term collections in Table 6.

Here *Torquigener pleurogramma* was again dominant, representing 77.4 per cent of individuals. Other species which were relatively common included *Centropogon australis, Myxus elongatus, Tetractenos glaber, Abudefduf vaigiensis* and *Epinephelus daemelii.*

In the short-term collections, the total numbers of species tended to increase with days since previous collection but this trend levelled off after 12 days and was similar to numbers of species shown in the long-term collections. The species which initially recolonized the defaunated tide pool were *Torquigener pleurogramma, Tetractenos glaber, Centropogon australis, Epinephelus daemelii* and *Microcanthus strigatus.*

Aggregating species showed a substantial increase in numbers three days following recolonization at the same time a decrease in solitary and cryptic species was observed. This may have been due to the increase in numbers of *T. pleurogramma* present in the 12-day and 38-day collections.

During the short-term collections life-history stages were determined for the eight most numerically abundant species. These species were collected predominantly as juveniles (Table 5). Larvae of *C. australis, E. daemelii* and *L. haplodactylus* and some adults of *T. glaber* and *A. ocellatus* were also collected. As a number of species were present only as juveniles (particularly *Myxus elongatus*) it is likely that adult fish do not stay in the pool. Hence, the short-term collections may indicate the importance of Seal Rocks tide pool as a nursery habitat.

DISCUSSION

Thomson and Lehner (1976) described an intertidal fish assemblage in the Gulf of California and Bennett and Griffiths (1984) and Beckley (1985a,b) studied South African tide pools. Thomson and Lehner (1976) indicated that subtidal fish assemblages generally have greater diversity than intertidal assemblages, yet qualitative evaluation in the

Table 5. Numbers of individuals of each species and life-history stages of the 16 numerically dominant species collected from the Seal Rocks tidal pool during the short-term series of collection (1986 ii–v).

Species	Days since previous collection						
	0.5	3	12	38	S_1	N%S_1	Stage
1. *Torquigener pleurogramma*	0	39	1 453	493	1 985	77.4	J
2. *Centropogon australis*	0	46	22	56	124	4.8	L–J
3. *Myxus elongatus*	2	9	15	79	105	4.1	J
4. *Tetractenos glaber*	9	19	10	54	92	3.6	J–A
5. *Abudefduf vaigiensis*	4	1	36	26	67	2.6	J
6. *Epinephelus daemelii*	0	19	1	25	45	1.8	L–J
7. *Lepidoblennius haplodactylus*	5	3	8	8	24	0.9	L–J
8. *Acanthistius ocellatus*	2	1	10	4	17	0.7	J–A
9. *Bathygobius fuscus*	2	0	3	10	15	0.6	
10. *Pardachirus hedleyi*	4	1	1	7	13	0.5	
11. *Girella elevata*	0	0	8	2	10	0.4	
12. *Parablennius intermedius*	2	0	3	4	9	0.4	
13. *Microcanthus strigatus*	0	0	3	5	8	0.3	
14. *Petraites nasutus*	1	2	0	3	6	0.2	
15. *Notolabrus gymnogenis*	0	1	2	3	6	0.2	
16. *Chironemus marmoratus*	0	0	0	6	6	0.2	

Abundances of the 16 numerically dominant species collected from the Seal Rocks pool during short-term collections; life history stages of the eight most numerically dominant: L, larval; J, juvenile; A, adult.

Table 6. Less common species collected from the Seal Rocks tidal pool since 1969.

ACANTHURIDAE
Acanthurus sp.
A. grammoptilus
Prionurus microlepidotus
BALISTIDAE
Balistidae sp.
BLENNIIDAE
Blenniidae sp.
BOTHIDAE
Engyprosodon grandisquamma
BYTHITIDAE
Dermatopsis macrodon
CHAETODONTIDAE
Chaetodon citrinellus
C. vagabundus
CHEILODACTYLIDAE
Cheilodactylus fuscus
Dactylophora nigricans
CLINIDAE
Cristiceps sp.
C. aurantiacus
Hetroclinus perspicillatus
Petriates heptaeolus
CLUPEIDAE
Herklotsichthys abbreviata
CYNOGLOSSIDAE
Paraplagusia unicolor
FISTULARIIDAE
Fistularia petimba
GOBIIDAE
Arenigobius bifrenatus
Favonogobius lateralis
HEMIRAMPHIDAE
Hemiramphidae sp.
ISONIDAE
Iso rhothophilus
HOLOCENTRIDAE
Holocentrus spinifer
KUHLIIDAE
Kuhlia taeniura
KYPHOSIDAE
Girella cyanea
G. tricuspidata
Kyphosus sydneyanus
LABRIDAE
Achoerodus viridis
Halichoeres nebulosus
Labridae sp.
Pictilabrus laticlavius
Pseudolabrus güntheri
Pseudolabrus sp.
LEPTOSCOPIDAE
Leptoscopus sp.
Crapatalus arenarius
MONACANTHIDAE
Monacanthus chinensis
MUGILIDAE
Mugil cephalus
MULLIDAE
Mulloidichthys sp.
Parupeneus signatus
OPICHTHYIDAE
Muraenichthys iredalei
OSTRACIONTIDAE
Lactoria diaphana
PEMPHERIDAE
Pempheris compressa
PLATYCEPHALIDAE
Platycephalus fuscus
PLESIOPIDAE
Trachinops taeniatus
POMACENTRIDAE
Abudefduf biocellatus
A. immaculatus
A. sordidus
Parma sp.
P. unifasciata
Plectroglyphidodon leucozona
Pomacentrus sp.
SCATOPHAGIDAE
Scatophagus argus
SCORPAENIDAE
Centropogon marmoratus
Dendrochirus brachypterus
D. zebra
Scorpaena cardinalis
SERRANIDAE
Acanthistius cinctus
Epinephelus sp.
E. tauvina
E. cyanopodus
E. rivulatus
E. septemfasciatus
SILLIGINIDAE
Sillago ciliata
S. maculata
SPARIDAE
Rhabdosargus sarba
Sparidae sp.
SYNODONTIDAE
Saurida gracilis
TETRADONTIDAE
Tetractenos hamiltoni
Torquigener sp.
TRIPTERYGIIDAE
Norfolkia striaticeps
Vauclusella sp.

present study shows that dominance by subtidal species in the Seal Rocks pool would appear to limit diversity. This contrasts with the findings of Thomson and Lehner (1976). Local characteristics of the particular tidal pools could explain the difference. At Seal Rocks there is a constant connection between the pool and the subtidal zone through a series of narrow passages.

As in other tidal pools described by Grossman (1982) and Beckley (1985a), the Seal Rocks tidal pool may serve as a nursery area for a number of species. The constancy of larvae of some species in the collections (e.g., *M. strigatus, M. elongatus, C. australis* and *E. daemelii*) indicates that these may settle in the pool (Tables 3, 5). The small size of some specimens collected for a number of other species (Table 3) suggests that settlement of these species occurs only opportunistically.

Factors involved in habitat selection at settlement are poorly known (Marliave 1977; Gibson 1982). Studies in South Africa (Beckley 1985a) suggest that the presence of juveniles within tidal pools is possibly due to the combination of active selection by some species and by the failure of others to move into more favourable environments, such as estuaries. Other, and probably more important nursery areas, have been described for some species such as seagrass meadows for the fortescue *C. australis* (Bell *et al.* 1978), and mangrove creeks for *M. elongatus* (Bell *et al.* 1984). However, in the Seal Rocks tide pool, further investigation is required to determine the relative importance of this type of habitat as nursery areas for these species.

Holling (1973) defined resilience as the persistence of a system without extinction. If this definition were applied to the repeated defaunation of an intertidal pool, the assemblage could be considered resilient if each major species recolonized the area within the time limits set by the between-defaunation interval. By this definition, if successive defaunation produced changes in the major species composition of the habitat within the time limits set by the between-defaunation interval, then that system would be considered not resilient. Collette (1986) reported resilience of a fish assemblage for New England tide pools in northeastern USA. Since the present study was qualitative, with no replicates or controls, the resilience of the Seal Rocks tidal pool cannot strictly be determined, but from the short-term study it would appear that it probably is resilient, in the terms of Holling's (1973) definition.

Intertidal pools may be defaunated through natural and human disturbances. Violent storms, temperature extremes, habitat destruction, pollution and recreational activities (Moring 1979) can cause partial or total defaunation of tidal pools. Little information is available on the responses of fish assemblages removed from tide pools through natural or other disturbances and recolonization of such habitats following natural defaunation remains to be elucidated. Studies of other assemblages of intertidal fish have shown that water temperature (Thomson and Lehner 1976; Jones and Clare 1977) and food availability (Grossman 1982) partly regulate these assemblages. Populations of several species common to Seal Rocks tidal pool have been shown to be thermoregulated in other areas (e.g., *A. vaigiensis*, Graham 1971; *Acanthurus triostegus*, Medvick and Miller 1979). Thus, water temperature may play an important role in determining the responses of some major species in the Seal Rocks assemblage.

This study is not an effort to provide an ecological evaluation of tide pools. It is a quantitative report of data collected from a single tide pool over a long period of time which, together with a short-term study furnishes information on fish assemblages in a selected tide pool and its response to artificial defaunation. With increasing use of coastal areas for recreation and human habitation, further studies on tide pools to assess their potential as nursery habitats need to be carried out. These would require replicate studies taken at regular intervals throughout the year over a period of at least two years, followed by two short-term studies. The short-term studies should be made the following year — the first from March to May as in this study with the second from September to November. Such a study would show the resilience (or otherwise) of the system and the use of tide pools as alternative nursery habitats.

REFERENCES

BECKLEY, L. E., 1985a. The fish community of East Cape tidal pools and assessment of the nursery function of this habitat. *S. Afr. J. Zool.* **19:** 21–27.

BECKLEY, L. E., 1985b. Tide-pool fishes: recolonization experimental elimination. *J. Exp. Mar. Biol. Ecol.* **85:** 287–95.

BELL, J. D., BURCHMORE, J. J. AND POLLARD, D. A., 1978. Feeding ecology of a scorpaenid fish, the fortescue *Centropogon australis*, from a *Posidonia* seagrass habitat in New South Wales. *Aust. J. Mar. Freshwat. Res.* **29:** 178–85.

BELL, J. D., POLLARD, D. A., BURCHMORE, J. J., PEASE, B. C. AND MIDDLETON, M. J., 1984. Structure of a fish community in a temperate tidal mangrove creek in Botany Bay, New South Wales. *Aust. J. Mar. Freshwat. Res.* **35:** 33–46.

BENNETT, B. A. AND GRIFFITHS, C. L., 1984. Factors affecting the distribution, abundance and diversity of rock-pool fishes on the Cape Peninsula, South Africa. *S. Afr. J. Zool.* **19:** 97–104.

BENNETT, B. A., GRIFFITHS, C. L. AND PENRITH, M., 1983. The diets of littoral fish from the Cape Peninsula. *S. Afr. J. Zool.* **18:** 343–52.

BRIGGS, J. C., 1974. *Marine Zoogeography.* McGraw-Hill: New York.

BUSSING, W. A., 1972. Recolonization of a population of supratidal fishes at Eniwetok Atoll, Marshall Islands. *Atoll Res. Bull.* **154:** 1–4.

BUTLER, G. S., 1982. Daily feeding periodicity of the intertidal goby *Caffrogobius caffer. S. Afr. J. Zool.* **17:** 183–9.

COLLETTE, B. B. C., 1986. Resilience of the fish assemblage in New England tidepools. *Fishery Bulletin* **84:** 200–4.

ENGEL, B. A., 1962. Geology of the Bulahdelah-Port Stephens District, NSW *J. Roy. Soc. NSW.* **95:** 197–215.

FISHELSON, L., 1970. Behaviour and ecology of a population of *Abudefduf saxatilis* (Pomacentridae:Teleostei) at Eilat (Red Sea). *Anim. Behav.* **18:** 225–37.

FUHRER, B., CHRISTIANSON, I. G., CLAYTON, M. N. AND ALLENDER, B. M., 1981. *Seaweeds of Australia.* A. H. and A. W. Reed Pty Ltd: Sydney.

GIBSON, R. N., 1967. Studies on the movements of littoral fish. *J. Anim. Ecol.* **36:** 215–24.

GIBSON, R. N., 1972. The vertical distribution and feeding relationships of intertidal fish on the Atlantic coast of France. *J. Anim. Ecol.* **41:** 189–207.

GIBSON, R. N., 1982. Recent studies on the biology of intertidal fishes. *Oceanogr. Mar. Biol. Annu. Rev.* **20:** 363–414.

GRAHAM, J. B., 1971. Temperature tolerances of some closely related tropical Atlantic and Pacific fish species. *Science* **172:** 861–63.

GRANT, E. M., 1982. *Guide to Fishes.* Department of Harbours and Marine: Brisbane.

GROSSMAN, G. D., 1982. Dynamics and organization of a rocky intertidal fish assemblage: the persistence and resilience of taxocene structure. *Am. Nat.* **119:** 611–37.

GUNDERMANN, N. AND POPPER, D., 1975. Some aspects of recolonization of coral rocks in Eilat (Gulf of Aqaba) by fish populations after poisoning. *Mar. Biol.* **33:** 109–17.

HOLLING, C. S., 1973. Resilience and stability of ecological systems. *Ann. Rev. Ecol. Syst.* **4:** 1–23.

JONES, D. AND CLARE, J., 1977. Annual and long-term fluctuations in the abundance of fish species inhabiting an intertidal mussel bed in Morecambe Bay, Lancashire. *Zool. J. Linn. Soc.* **60:** 117–72.

LEIS, J. M. AND RENNIS, D. S., 1983. *The Larvae of Indo-Pacific Coral Reef Fishes.* New South Wales University Press: Sydney and University of Hawaii Press: Honolulu, in association with The Australian Museum.

LENANTON, R. J. C., 1982. Alternative non-estuarine nursery habitats for some commercially and recreationally important fish species of south-western Australia. *Aust. J. Mar. Freshwat. Res.* **33:** 881–900.

MARLIAVE, J. B., 1977. Substratum preferences of settling larvae of marine fishes raised in the laboratory. *J. Exp. Mar. Biol. Ecol.* **27:** 47–60.

MARSH, B., CROWE, T. M. AND SIEGFRIED, W. R., 1978. Species richness and abundance of clinid fish (Teleostei, Clinidae) in intertidal rock pools. *Zool. Afr.* **13:** 283–91.

MEDVICK, P. A. AND MILLER, J. M., 1979. Behavioural thermoregulation in three Hawaiian reef fishes. *Env. Biol. Fish.* **4:** 23–8

MISKIEWICZ, A. G., 1991. Larval Biology. Pp. 170–93 in *Proceedings No. 15. Australian Society for Fish Biology Workshop* ed by D. A. Hancock.

MORING, J. R., 1979. Pacific Coast intertidal fishes. *Sea Frontiers* **25:** 22–30.

MUNRO, I. S. R., 1954–58. *Handbook of Australian Fishes.* Australian Fisheries Newsletter.

MUNRO, I. S. R., 1967. *The Fishes of New Guinea.* Department of Agriculture, Stock and Fisheries: Port Moresby.

POTTS, G. W., 1980. The littoral fish of Little Cayman (West Indies). *Atoll. Res. Bull.* **241:** 43–52.

RICHKUS, W. A., 1978. A quantitative study of intertidepool movement of the woolly sculpin *Clinocottus analis. Mar. Biol.* **49:** 277–84.

SALE, P. F., 1969. Pertinent stimuli for habitat selection by the juvenile manini, *Acanthurus triostegus sandvicensis. Ecology* **50:** 616–23.

SCOTT, T. D., GLOVER, C. J. M. AND SOUTHCOTT, R. V., 1974. *The Marine and Freshwater Fishes of South Australia.* A. B. James, Government Printer: South Australia.

THOMSON, D. A. AND LEHNER, C. E., 1976. Resilience of a rocky intertidal fish community in a physically unstable environment. *J. Exper. Mar. Biol. Ecol.* **22:** 1–29.

YOSHIYAMA, R. M., 1981. Distribution and abundance patterns of rocky intertidal fishes in central California. *Env. Biol. Fish.* **6:** 315–32.